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AWARDS ABSTRACT

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NASA Case . NPO-13573-1

Contractor: Jet Propulsion Laboratory

Contract NAS7-100

RAW LIQUID WASTE TREATMENT SYSTEM AND PROCESS

The present invention is directed to a new process and system for treating raw liquid waste, such as raw sewage.

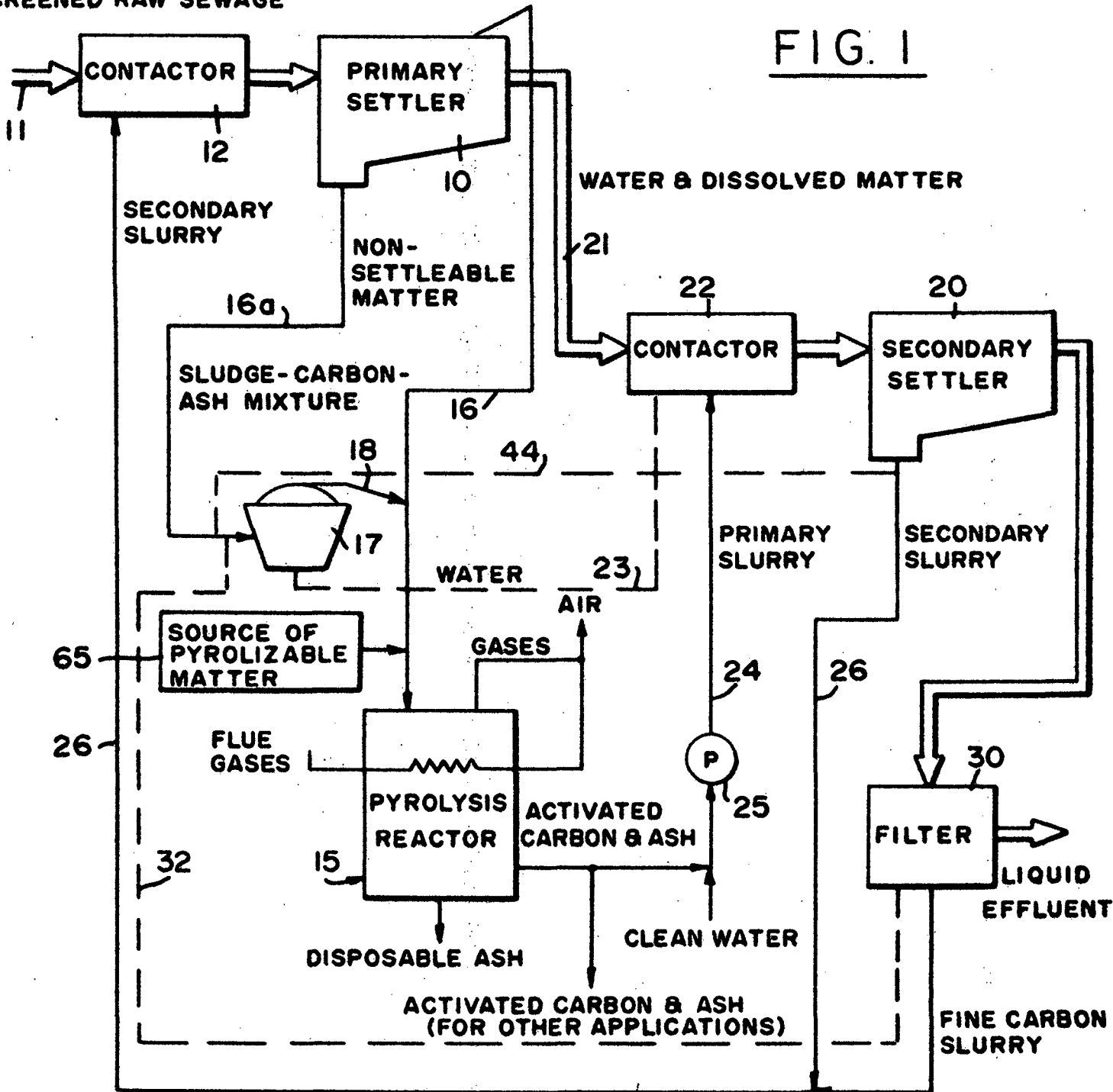
In the process, substantially all the non-dissolved matter in the raw sewage is first removed from the sewage water in a primary settler 10 (Figure 1). The separation is facilitated by the addition of partially used activated carbon and ash material which was already used downstream. The sewage water from which the non-dissolved matter was removed is directed to a secondary settler 20. This water contains dissolved organic matter. The separated non-dissolved matter together with the used activated carbon and ash material from the primary settler are filtered by filter 18 to remove the water therefrom and are supplied to a pyrolysis reactor 15 wherein they are converted into fresh activated carbon and ash material. The latter, in the form of a primary slurry, is combined in settler 20 with the water in which organic matter is dissolved. The fresh activated carbon and ash material desorbs the dissolved organic matter and thereafter is returned via line 26 upstream to the primary settler to facilitate the separation of the non-dissolved matter from the incoming raw sewage. If the raw sewage is highly contaminated, any excess activated carbon and ash material, produced by reactor 15 and not needed for the water treatment, may be exploited commercially. If water treatment is not of concern, the process can be employed to produce commercially-exploitable carbon and ash material with raw sewage as the source material. The invention can be used to treat water-containing industrial waste, e.g., fish waste (Figure 6) by treating the water for recycling or for disposal as well as to extract from the fish waste useful products, such as fish solids and fish oils. Some of the fish solids may be used as the pyrolyzable matter to produce the needed carbon and ash material. Figure 7 is a diagram of a system incorporating the present invention to treat different waste products from a sugar beet process.

The novelty of the invention is believed to reside in the formation of the activated carbon and ash material from the sewage contaminants without the addition of any reagents and, more particularly, in the use of this material first downstream to remove dissolved organic matter and only thereafter upstream to facilitate the removal of non-dissolved matter from the incoming raw sewage. The novelty of the invention also enables its use to produce commercially-useful carbon and ash material from raw sewage, as well as apply the process to water-containing industrial wastes, to treat the water either for reuse or proper disposal and to extract useful matter from the industrial waste.

Application Serial No. 501,014
Filed: August 27, 1974

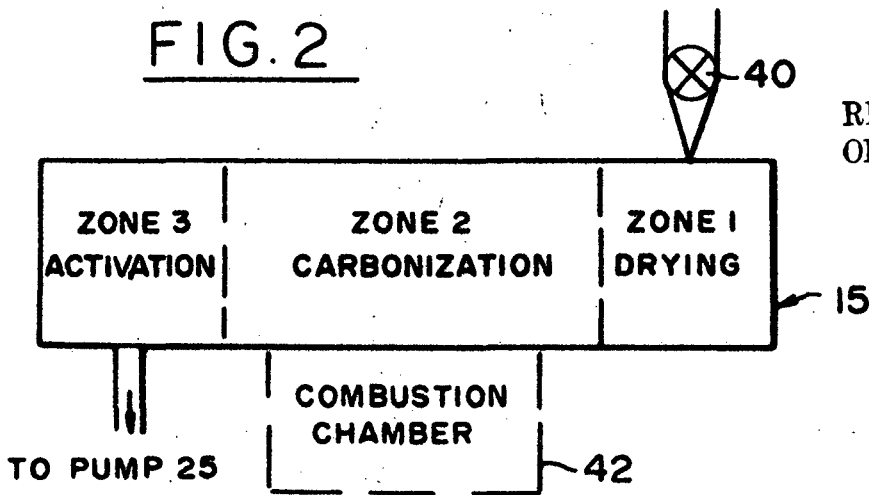
SCREENED RAW SEWAGE

FIG. 1



FROM LINES 16 & 18

FIG. 2



REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

FIG. 3

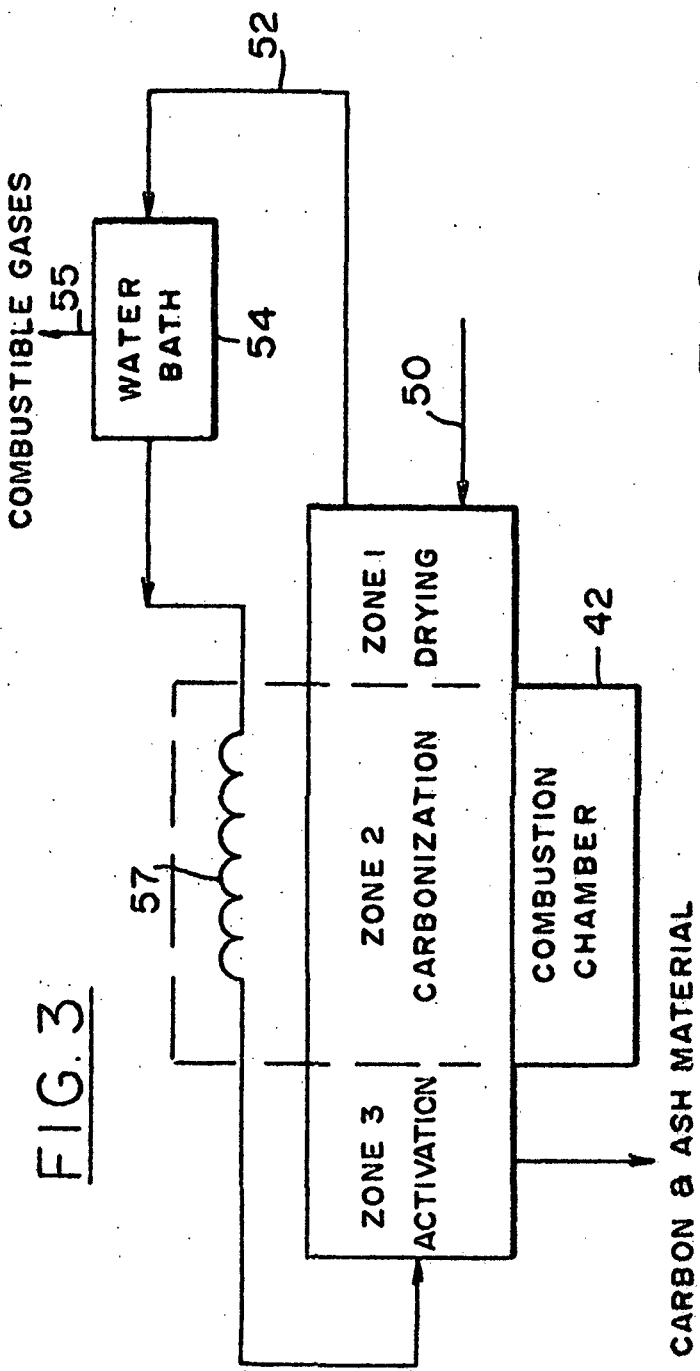


FIG. 6

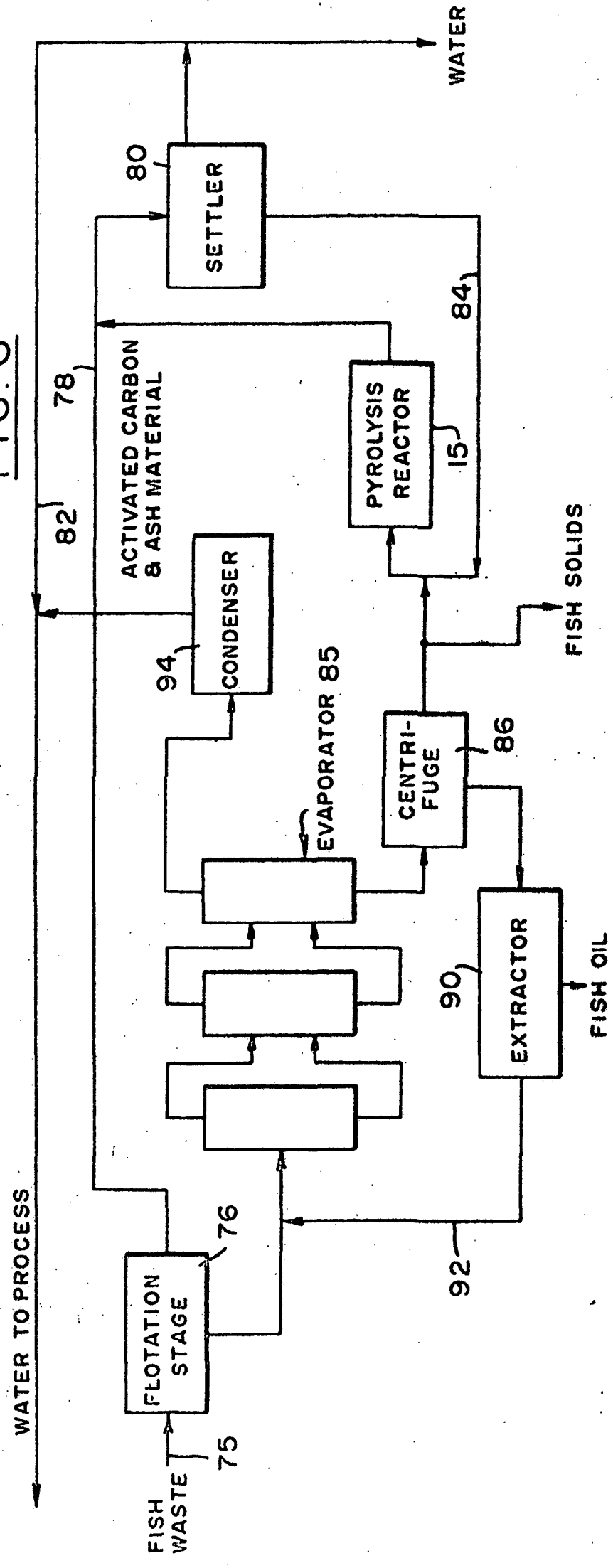
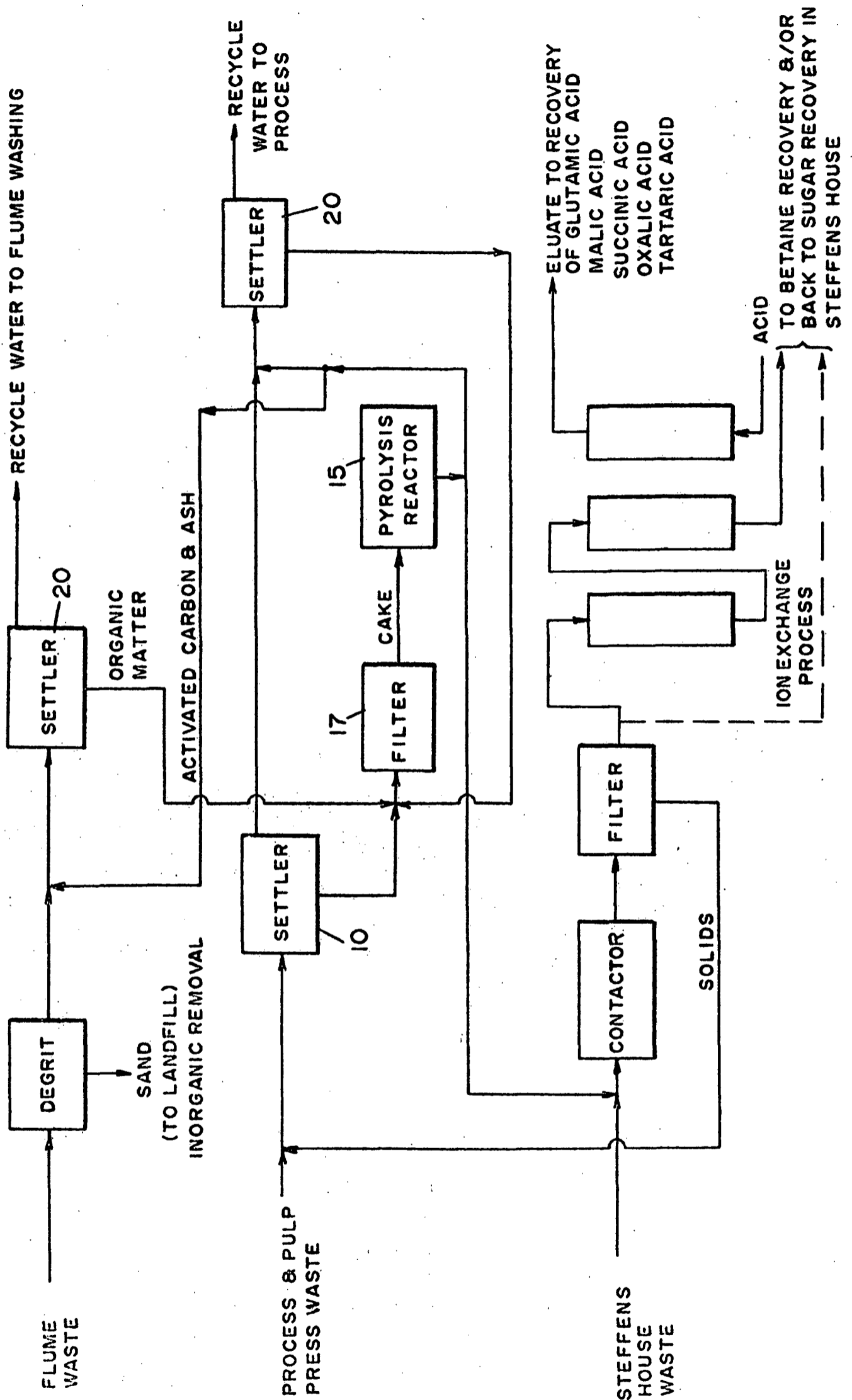


FIG. 5

SOLIDS REMOVAL (mg/l)					
RESULTS	TOTAL SUSPENDED SOLIDS (TSS)	VOLATILE SUSPENDED SOLIDS (VSS)	GREASE	* BOD	
EFFLUENT CONCENTRATION (AVE.) (OUT OF 10)	75	51	10	16	
% REMOVED	85	87	88	91	
HEAVY METALS (mg/l)					
RESULTS	SILVER	CADMIUM	COPPER	NICKEL	ZINC
EFFLUENT CONCENTRATION (AVE.)	0.006	0.048	0.320	0.190	0.380
% REMOVED	77	79	38	41	63
* BOD = BIOCHEMICAL OXYGEN DEMAND					

HEAVY METAL REMOVAL (mg/l)					
COMMERCIAL CARBON (NUCHAR)	SILVER	CADMIUM	COPPER	NICKEL	ZINC
INFLUENT	0.006	0.057	0.58	0.24	1.11
PLANT EFFLUENT	0.002	0.024	0.027	0.12	0.12
% REMOVED	67	58	95	50	89
PYROLYSIS REACTOR PRODUCT	SILVER	CADMIUM	COPPER	NICKEL	ZINC
INFLUENT	0.016	0.30	0.74	0.32	1.01
PLANT EFFLUENT	0.002	0.026	0.017	0.13	0.07
% REMOVED	88	84	97	63	93

FIG. 4



S P E C I F I C A T I O N

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT MARSHALL F. HUMPHREY, a citizen
of the United States of America, residing at Duarte, in
5 the County of Los Angeles, State of California, has invented
a new and useful

RAW LIQUID WASTE TREATMENT SYSTEM AND PROCESS

of which the following is a specification:

ABSTRACT OF THE DISCLOSURE

10 A raw sewage treatment process is disclosed in
which substantially all the non-dissolved matter, which is
suspended in the sewage water is first separated from the
water, in which at least organic matter remains dissolved.
The non-dissolved material is pyrolyzed to form an activated
15 carbon and ash material without the addition of any condition-
ing agents. The activated carbon and ash material is added
to the water from which the non-dissolved matter was removed.
The activated carbon and ash material adsorbs the organic
matter which is dissolved in the water and is thereafter
20 supplied in a counter current flow direction and combined
with the incoming raw sewage to at least facilitate the
separation of the non-dissolved settleable materials from the
sewage water. The used carbon and ash material together with
the non-dissolved matter which was separated from the sewage
25 water are pyrolyzed to form the activated carbon and
ash material.

CROSS REFERENCE TO RELATED APPLICATION

This application is a Continuation-In-Part of application Serial No. 390,467 filed August 22, 1973.

ORIGIN OF INVENTION

5 The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 USC 2457).

BACKGROUND OF THE INVENTION

10 1. Field of the Invention:

 The present invention generally relates to a waste water treatment process and, more particularly, to a process and system for treating raw liquid waste which contains
15 organic matter which is dissolved and/or suspended in the liquid.

 2. Description of the Prior Art:

 The problems facing municipalities in treating raw sewage, which is one form of waste water, are well known.
20 The sewage consists of water contaminated by organic and inorganic matter which is dissolved in the water as well as organic and inorganic matter which is not dissolved, namely suspended in the water. The latter-type contaminant may be divided into two groups of materials, those which are settleable

in the water and those which are not settleable and tend to float on top of the water. The function of any sewage treatment system is to separate substantially all the suspended matter from the water as well as to greatly reduce the organic matter dissolved therein, and thereafter dispose of the separated matter.

The separated contaminants which are mixed with some water and therefore are in slurry form, often referred to as sludges, are biologically active until stabilized by subsequent treatment. The stabilization is generally achieved by biological digestion. Such digestion is sometimes used to produce combustible gases such as methane, useful as a source of energy. However, the remaining solid material presents difficult and costly disposal problems. Digested (humic) solids have been processed to fertilizers and soil conditioners. This practice is generally not economical and the quantity available greatly exceeds the market demands. Municipalities are finding it increasingly difficult to dispose of the remaining sludge solids in waterways, oceans or landfills due to their ecological impact. Legislation is being considered to reduce and eventually forbid such solid dumping. Thus, disposal of solids, produced by prior art treatment systems, present a very severe problem, in addition to the high disposal cost. Other disadvantages of prior art systems in which biological digestion is employed include the large land area of aeration basins required for their operation, and the releasing of offensive odors. Also, prior art systems are

relatively inefficient and must be carefully monitored and controlled to prevent any unbalancing in the biological digestion. That is, the types and/or amounts of contaminants per liter of water must be controlled to be within specified
5 limits in order not to upset the biological digestion process.

An attempt to reduce the amount of solids requiring disposal is described in U.S. Patent No. 3,640,820. Therein, a sewage treatment process is described in which the sewage sludges are converted into an active material which
10 is used in the process. Several disadvantages of the system described in said patent are apparent. The proposed process is one employing biological digestion and therefore suffers from all of the shortcomings, hereinbefore discussed. In addition, it requires the use of a conditioning agent in the
15 active material production.

In the February 22, 1972 issue of Chemical Engineering, a process developed by DuPont and known as PACT for Powdered Activated Carbon Treatment is disclosed. Therein, activated carbon, which is not produced from contaminants
20 in liquid waste is required, thereby increasing process costs. Also, the amount of material, requiring final disposal, is not reduced and therefore the disposal cost is high and the disposal problems are not solved.

OBJECTS AND SUMMARY OF THE INVENTION

25 It is a primary object of the present invention to provide a new sewage treatment system and process.

Another object of the invention is to provide a sewage treatment process in which the contaminants are used to form a material without the addition of a conditioning agent, with the material being used in the treatment process.

5 Yet another object of the invention is to provide a highly efficient sewage treatment process in which biological processing is not required and in which substantially all the objected-to contaminants are removed in the process by means of a material which is formed from the contaminants, with the
10 amount of material requiring final disposal being inert and only a fraction of the total amount of contaminants.

These and other objects of the invention are achieved by a treatment process in which at least the non-dissolved matter, hereinafter also referred to as solids of
15 screened raw sewage are separated in a primary settler from the water which contains the dissolved organic and inorganic matter. As will be pointed out hereinafter, the separation of the non-dissolved settleable solids from the water is facilitated by the addition of a slurry of an activated carbon
20 and ash material which has been used down-stream in the process. The non-dissolved settleable solids together with the slurry of the activated carbon and ash material, which settle on the bottom of the primary settler, are removed as a wet slurry-and-primary-sludge mixture from the primary settler
25 and supplied to a filter. Therein, the mixture is supplied to a pyrolysis reactor. The latter is also supplied with the non-dissolved nonsettleable contaminants (solids) from the top of the primary settler.

In the reactor, the material which is supplied thereto, is converted into a material which consists of activated carbon and ash. The activated carbon and ash material is formed into a primary slurry by the addition of water and is added to the water from which the non-dissolved matter has been separated in the primary settler. The water and the activated carbon and ash are introduced into a secondary settler, wherein a very high percentage of the organic matter, which is dissolved in the water, is adsorbed onto the carbon and ash. The latter, after adsorbing the dissolved organic matter is removed from the secondary settler as a secondary slurry, and is directed to the primary settler into which the screened raw sewage is initially introduced. The addition of the secondary slurry, i.e., the partially used carbon and ash material to the screened raw sewage greatly reduces the separation time of the non-dissolved settleable matter from the sewage water. In addition, the presence of the carbon in the slurry-and-primary-sludge mixture which is supplied to the filter acts as a filtering aid. It promotes faster dewatering of the mixture and therefore drier material for the pyrolysis step.

The novel features of the invention are set forth with particularity in the appended claims. The invention will best be understood from the following description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a general block diagram of the novel system and process of the present invention;

Figure 2 is a simplified cross sectional view of one possible embodiment of a pyrolysis reactor, shown in Figure 1;

Figure 3 is a simplified diagram of a different embodiment of the reactor;

Figures 4 and 5 are diagrams in table form useful in explaining the advantages of the invention; and

Figures 6 and 7 are diagrams showing the use of the principles of the present invention in industrial processes.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Attention is now directed to the drawing wherein numeral 10 designates a primary settler of a sewage treatment system in accordance with the present invention. As is known, raw sewage or wastewater consists of water which is contaminated by various organic and inorganic materials, some of which are dissolved in the water, while others are non-dissolved and are suspended therein. The non-dissolved suspended materials are either of the settleable or the non-settleable types. The latter tends to float on top of the water. The function of any raw sewage treatment process is to remove the non-dissolved suspended materials, and as much as possible of the dissolved organic matter from the water.

In accordance with the present invention, biologically untreated raw sewage is first screened by appropriate means (not shown), in a manner well known in the art, to remove all relatively large objects as well as most of the sand in the

raw sewage. The biologically untreated screened raw sewage, hereinafter simply referred to as screened sewage or simply sewage, which is fed to the system on line 11 is introduced into a contactor or flocculator 12 wherein it is mixed with an incoming secondary slurry. As will be described hereinafter, the incoming secondary slurry is a slurry of activated carbon and ash material which was partially used down stream. After appropriate mixing, the mixture of the screened sewage with the secondary slurry is fed to the primary settler 10.

In the present invention, substantially all of the non-dissolved suspended solid material is removed from the sewage water in settler 10. The non-settleable material, which is generally skimmed off the top of the water, is supplied to a pyrolysis reactor 15 directly via line 16.

The non-dissolved settleable material together with the slurry of the activated carbon and ash material which is added to the sewage in contactor 12 tend to settle at the bottom of the settler 10 as a mixture. Since the non-dissolved settleable material in sewage is sometimes referred to as primary sludge or sludge, the mixture settling at the bottom of the settler 10 can be thought of as a sludge and slurry mixture or as a sludge-carbon-ash mixture, since the slurry is a material containing both carbon and ash.

The sludge-carbon-ash mixture which settles at the bottom of the settler 10 is removed therefrom via line 16a. At this point, it is very wet. Therefore, via line 16a, it is supplied to a filter 17 whose function is to dewater the mixture. The dewatered mixture in the form of relatively dry cakes of solids is supplied to the reactor 15 via line 18.

Thus, the reactor 15 is supplied with all the non-dissolved suspended matter, both organic and inorganic, present in the incoming screened sewage.

5 The sewage water from which all the suspended matter was removed in settler 10, is supplied via line 21 to a contactor 22 and therefrom to a secondary settler 20. The water from filter 17, which is relatively free of any suspended matter is preferably combined with the effluent of settler 10 in line 21 or in contactor 22, as represented by dashed line
10 23.

As is appreciated, the settling time of settleable contaminants in screened sewage is quite long. It has been discovered that the settling time for all non-dissolved settleable matter can be reduced to less than an hour by mixing
15 the screened sewage in the contactor 12 with a material consisting of activated carbon and ash and thereafter introducing the mixture into settler 10 wherein settling takes place. The settling rate of the non-dissolved settleable matter seems to depend on the ash content as well as the carbon particle
20 size of the activated carbon and ash material. Tests with an activated carbon and ash material with about 50% ash and small particle size produced total settling (in settler 10) of all settleable matter in 35 minutes, as compared with the commercial carbon, containing little or no ash, which showed very poor
25 settling characteristics. With such material, fine matter remained in suspension for as long as 24 hours.

The activated carbon tends to adsorb to some extent various substances, such as DDT, phosphates, nitrogenous substance, some metal salts, and organic complexes of mercury which are not easily separable from water by other means. It has been discovered that the addition of the carbon and ash material reduces turbidity, removes odors and reduces foaming. In some runs, it was found that the skimming of the settler 10 to remove the non-dissolved nonsettleable matter such as greases, and other floating matter was not necessary, since such matter tended to settle with the rest of the non-dissolved matter as a result of the dispersion and flocculation produced in the mixing in contactor 12. Thus, in some applications, line 16 may be eliminated.

It is thus seen that the mixing of the activated carbon and ash material with the incoming sewage greatly facilitates the settling of the non-dissolved matter therein. In addition to this significant advantage, an advantage results from the presence of the carbon in the sludge-carbon-ash mixture which is supplied to the filter 17. The presence of the carbon in this mixture is very helpful in the filtering operation. The carbon acts as a filtering aid. It tends to promote faster filtering and higher dewatering of the mixture. Thus, drier material is supplied from the filter 17 to the reactor 15.

From the foregoing, it is thus seen that the reactor 15 is supplied with the relatively dry cakes of solids from the filter 17 and with any non-settleable sewage contaminants which may be skimmed off the top of the primary settler 10.

In the reactor, all the supplied material is pyrolyzed under controlled temperature and pressure conditions and is converted into an activated material which consists of activated carbon and ash. This is achieved without the addition of any conditioning agents. As part of the pyrolysis operation, various gases, including combustible gases, such as methane and carbon monoxide, may be released. Such gases may be used to provide at least part of the energy needed for the system's operation.

It is believed that the ash component in the produced activated carbon and ash material represents primarily the pyrolyzed inorganic matter, the major components of which are believed to be calcium, magnesium, iron, phosphates, sulphates and oxides. The carbon components represent the pyrolyzed organic matter. A careful inspection of the material reveals that it does not consist of a mixture of separate carbon particles and ash particles but rather of particles which are a combination of carbon and ash. As previously indicated in tests, it has been noted that the activated carbon and ash material produced from typical domestic screened raw sewage with about a 50% ash content was found to be very useful in the separation of the non-dissolved matter from the water in the primary settler 10.

It should be stressed that the material produced in the reactor 15 is activated rather than inactivated carbon and ash. Activated carbon and various techniques of producing it are described in a book entitled "Activated Carbon" by John W. Hassler, published in 1963 by Chemical Publishing Company, Inc., of New York.

The fresh activated carbon and ash from the reactor 15 is combined with clean water to form a primary carbon-ash slurry which is supplied to the contactor 22, via line 24. The latter may incorporate a pump 25 to pump the primary carbon-ash slurry to the contactor 22. The pump which may be a centrifugal pump may also be used to control the average size of the particles of the carbon and ash material. The fresh activated carbon and ash is mixed in contactor 22 with the water, from which all non-dissolved matter was previously removed in settler 10, and which now contains only the dissolved matter, both organic and inorganic. This mixture is then supplied to the secondary settler 20. Therein, the activated carbon and ash adsorbs a very high percentage of the dissolved organic matter and settles on the bottom of settler 20.

The adsorption efficiency was found to be quite high due to the fact that the adsorbing carbon is the fresh carbon from the reactor 15. Also, since the water in settler 20 is free from any non-dissolved contaminants such as greases, which were removed in the primary settler 10, the carbon-ash particles do not become coated with any matter which may inhibit the adsorbability of organic matter thereon. The activated carbon and ash material is capable of adsorbing the organic matter, dissolved in the water, even at relatively low organic matter concentration. It has been discovered that very good results are achieved when the primary carbon-ash slurry contains an amount (by weight) of carbon about equal to the amount of total organic matter in the original screened

sewage which enters the primary settler 10. After an appropriate contact time, e.g., 20 minutes, the activated carbon and ash, which adsorbed the organic matter is removed as a secondary carbon-ash slurry from settler 20 and is supplied, via line 26, to the contactor 12, to which the original screened sewage is supplied.

The reasons for adding the secondary carbon-ash slurry to the raw sewage have been previously discussed. Even though the carbon and ash material in the secondary slurry was already partially used in the secondary settler 20, its usefulness is not at an end. It facilitates the separation of the non-dissolved suspended matter of the sewage in addition to adsorbing or otherwise removing some materials which are difficult to otherwise separate from the water. The partially used activated carbon and ash in the primary settler 10 is also believed to adsorb some of the inorganic and organic matter dissolved in the water. However, its primary function is to facilitate the separation of non-dissolved matter from the sewage water.

From the foregoing, it is thus seen that in accordance with the present invention, an activated carbon and ash material is formed from the contaminants of the screened sewage without the addition of any conditioning agents. This activated carbon and ash material (as the primary carbon-ash slurry) is first used to adsorb most of the organic matter dissolved in the sewage water from which non-dissolved matter was previously removed. Then, the partially used carbon and ash material (as the secondary carbon-ash slurry) is mixed with the incoming raw sewage. The presence of this material

facilitates the separation of non-dissolved matter from the sewage water by greatly reducing the settling time. The wet non-dissolved matter, together with the used carbon and ash material are then supplied as a sludge-carbon-ash mixture to the filter, whose function is to reduce the mixture water content. The carbon present in the mixture acts as a filtering aid which increases filtering rates and reduces the water content of the solid materials which are supplied to the reactor 15 for pyrolysis.

From the foregoing, several significant advantages of the present invention should become apparent. First, the present invention eliminates the biological digestion stage, such as an aeration basin, which is typical of most prior art systems. Its elimination reduces system size, complexity and cost. Secondly, all the material which is needed for the treatment process, i.e., the activated carbon and ash material is produced from the sewage contaminants without any biological treatment and without the need for any additional conditioning agents.

Tests of the present invention with typical screened sewage indicate that in the pyrolysis step, in addition to the activated carbon and ash material, sufficient combustible matter and gases are formed which can provide nearly all the power necessary to sustain the system's operation. Thus, energy from external sources may not be required. Also, these tests indicate that the amount of material which has to be disposed of is only about 1/10 the total contaminant materials in the sewage, thereby greatly reducing the material disposal problem.

In the present invention optimum use is made of the produced activated carbon and ash material. It is first used to adsorb the organic matter, dissolved in the water, from which non-dissolved matter was already removed. This prevents greases and other contaminants from coating the carbon and ash particles and thereby inhibit their adsorbability of dissolved organic matter. Only after adsorbing such matter is the partially used carbon and ash material, referred to as the secondary carbon-ash slurry, used up stream to facilitate the settling of the non-dissolved matter in the sewage in settler 10 and thereafter to facilitate the dewatering of the mixture in the filter 17.

This point is quite significant since some raw sewage may not contain sufficient contaminants to produce more than necessary carbon and ash material. Therefore, in order to avoid the need of adding carbon and ash material from an outside source, optimum use must be made of the material produced only from the contaminants in the raw sewage. It should be clear that when starting the system, some activated carbon and ash material need be available. However, under running conditions, it is believed that sufficient activated carbon and ash material is produced from the contaminants in the system's influent, i.e., the raw sewage, so that no additional carbon and ash material is needed.

As previously pointed out, the ash represents primarily the pyrolyzed inorganic matter. However, as the carbon and ash material circulates through the system and is repeatedly pyrolyzed together with the contaminant matter which is supplied to the reactor 15 from filter 17,

some of the carbon burns to form ash. Thus, the ash content tends to increase. The ash content can be controlled by controlling the amount of the ash which is disposed out of the reactor and removed from the system. Under running conditions in one test, it was found that the ash content can be held to be about 50% in the activated carbon and ash material under running operating conditions. Such a composition was found very useful in reducing settling time in the primary settler. It should be pointed out however, that the ash content may be varied over a wide range without departing from the spirit of the invention. For any system reduced to practice, the ash content may be varied so as to minimize the settling time in settler 10, yet insure that the material contains sufficient carbon to adsorb the organic matter in settler 20 and to act as a filter aid in filter 17.

The basic system in accordance with the present invention is effectively a non-biologically digestion two stage system, since it includes only the primary and secondary settlers in the water flow path. Laboratory tests indicate that with the present system and process between 87 and 93% of all organic matter can be removed from the water after passing through the secondary settler. In the prior art, two stage systems, with one of the stages being a biological digestion stage, only about 80-85% of the organic matter is removed. Thus, the present system is clearly more efficient.

It is believed that the organic matter remaining in the water, in settler 20 after it was treated by the fresh activated carbon and ash material consists of matter of high molecular weight which is generally not adsorbable by carbon.

By hydrolyzing the raw sewage in the primary settler or ahead of it, the molecular weight of such matter may be lowered so that even a higher percentage of the organic matter will become adsorbed by the carbon. Thus, hydrolysis may increase the system's efficiency.

In practice, most of the activated carbon and ash material which is introduced into the secondary settler 20 settles therein and is removed therefrom as the secondary carbon-ash slurry. However, the carbon and ash material may include some very small particles which tend to remain suspended in the water in the secondary settler. They can be removed by passing the water effluent from the secondary settler 20 through an appropriate filter, designated by numeral 30. The carbon particles, trapped by filter 30, may then be removed from the filter in the form of a fine carbon slurry and thereafter be combined with the secondary carbon-ash slurry, for subsequent use in the primary settler 10. Alternatively, the fine carbon slurry from filter 30 may be supplied directly to the filter 17 as indicated by dashed line 32, for use therein together with the other matter which is supplied thereto from the primary settler 10.

It should be appreciated that for the system to be self-sustaining, at least as far as the production of the activated carbon and ash material, the treated sewage should contain a sufficient amount of organic contaminants. Processed typical domestic raw sewage contains a sufficient amount of such contaminants. The average composition of domestic raw sewage has been described in the literature and is well known by those familiar with the art.

The present invention is capable of processing sewage with higher than conventional contaminant content. This is not the case in prior art systems in which biological digestion is employed. Therein, the types of contaminants, such as toxic chemicals and/or their amounts cannot exceed certain limits. Otherwise, the biological digestion process is greatly upset which often causes the entire treatment process to be shut down. It is this high sensitivity of prior art systems, which employ biological digestion to over-contaminated sewage, or to liquid wastes which contain certain contaminants, e.g., chromium, acids, and alkalies, which often force municipalities to inhibit various industries from injecting their wastewater into the wastewater networks of the municipalities.

However, in the process of the present invention, if the sewage contains higher than conventional contaminant content, it is in no way detrimental. The higher contaminant content may result in the production of more activated carbon and ash material than is necessary for self-sustaining the process. Any excess activated carbon and ash material may be used as a source of additional energy for the system's operation or for any other purposes which are completely separate from and independent of the system and process of the present invention.

Manufacturers of activated carbon are searching for sources of material to produce activated carbon for different applications. Thus, the present invention may be utilized for the production of activated carbon and ash material. It should thus be apparent that the production of more

activated carbon-and-ash material than is necessary for the system, rather than being a disadvantage, is a significant advantage, since the excess carbon-and-ash material may be commercially exploited. Manufacturers of activated carbon, not concerned with the treatment of sewage, may use the teaching of the invention to produce such carbon from the contaminants in sewage. In such production the step of first using the fresh carbon to remove the dissolved organic matter in settler 20 may be eliminated. The raw sewage can be used to produce the fresh activated carbon and ash material. Some of this material will be fed back to the first contactor 12 to facilitate the settling of the non-dissolved matter in the sewage, while the non-used carbon and ash material will be removed from use in different applications.

Although the invention has been described in connection with treating screened raw sewage, it should be apparent that it is applicable to treat any type of wastewater, which is contaminated by organic and inorganic materials. Screened raw sewage is only one type of wastewater. Furthermore, the invention can be used to treat any liquid, contaminated by organic and inorganic materials, in any industrial or agricultural process. As used herein, the term raw liquid waste intends to refer to any contaminated liquid, including water but not limited thereto. For example, the present invention may be used to treat raw liquid waste produced in an industrial or agricultural process in order to enable the liquid to be reused. Also, it may be used to reduce the contaminant content of the liquid waste to permit the liquid to be injected in the general wastewater network of a neighboring municipality or into the natural surroundings.

In one embodiment which was actually reduced to practice, very satisfactory activated carbon and ash material was produced in reactor 15 which operated at a temperature between 1200 and 1800 degrees Fahrenheit (660 to 982 degrees Centigrade) under an atmosphere composed of a mixture of gases. The mixture of gases, at a pressure slightly higher than atmospheric pressure, was composed of the gases derived from the pyrolysis operation consisting mainly of carbon dioxide, carbon monoxide, hydrogen and water vapor in the form of superheated steam. The pyrolysis reactor 15 consisted of three principal reaction zones comprised of: Zone 1, water evaporation or drying; Zone 2, carbonization or decomposition; Zone 3, activation or selective oxidation, as shown in simplified form in Figure 2. The matter supplied to the reactor 15 on lines 16 and 18 was introduced into Zone 1 through a valve 40. The matter was advanced from zone to zone by rakes supported on a rotatable shaft (not shown). Heat was provided by a combustion chamber 42. The mixture of gases which was formed served to dry the matter in Zone 1 as well as activated the carbon in Zone 3. As is appreciated, some of the gases, such as methane and carbon monoxide which are combustible and which are released during the process, can be used as a source of energy. Superheated steam was used for the carbon activation.

Retention time in Zone 3 determined the degree of activation and varied from 15 minutes to one hour. Retention time is a function of the reactor furnace design and can vary from as little as five seconds to as much as five hours. Longer times for activation tend to produce greater activation of the carbon but reduce the proportion of carbon

and increase the proportion of ash. Lower retention times for activation tend to decrease the degree of activation and increase the proportion of carbon and decrease the proportion of ash. The activation retention times of 15 minutes to one hour was found to produce the proper degree of activation and the proper combination of carbon and ash for satisfactory operation of the process.

Another test reactor 15, which was actually used in various tests, is diagrammed in Figure 3. This particular test reactor is a single cylinder or tube approximately 60 inches long, divided into the three zones Z1-Z3 of lengths of 12, 30 and 18 inches respectively. The feed rate of material to be pyrolyzed was adjusted to vary between 5 and 20 lb/hr of dry material. In Figure 3, line 50 designates the material input line, such as from valve 40 (see Figure 2). Rakes (not shown) in the reactor continually turned the material passing therethrough. The carbonization zone or zone 2 is heated by means of a surrounding combustion chamber 42 to a temperature of about 1900°F, while the drying zone or zone 1 is at at least 212°F at atmospheric pressure. Therein, steam and volatile gases which become separated from the input material exit through line 52. They are directed to a water bath 54, wherein the steam condenses and the combustible gases exit through line 55.

Water from bath 54 is made to pass through a coil 57 at the top or stack of the combustion chamber. In the particular reactor the water, as it passes the coil 57, is converted into superheated steam at a temperature of about 1200°F to 1300°F. The superheated steam enters the activation

zone or zone 3 via line 58 to activate the carbon in the hot matter which is fed into zone 3 from zone 2. The superheated steam, which is at a lower temperature than the hot matter entering zone 3 from zone 2, tends to lower the temperature in zone 3 to about 1800°F. The steam flows from zone 3 through zone 2 to zone 1 wherein it helps to heat this zone as well as purge or sweep out all the gases from zone 1 to the water bath 54.

The steam activation rate is controlled. In the test conducted it was adjusted to about 5.23 lbs of water per hour, for a dry material feed rate of about 15 lbs/ hour. The activated carbon and ash material exits the zone 3 through line 60. Since the carbon is hot it needs to be protected from oxygen so as not to burn up. It can be collected in a non-oxygen atmosphere until cooled or by directly dumping into a water bath, for cooling purposes. The resulting activated carbon-and-ash material was analyzed to determine particle size distribution. About 60% of the particles were of mesh size of 80 to 325.

The activated carbon and ash material produced by this reactor from conventional type raw sewage was found to be very satisfactory in the treatment process. Analysis tests were performed on the system influent, i.e., the incoming raw sewage and the system effluent, i.e., the water leaving the secondary settler 20 or filter 30. It was discovered that with the activated carbon and ash material, produced in accordance with the present invention and the manner in which it was used as hereinbefore described, the efficiency of removing various heavy metals is greater than when commercially available carbons are used. These metals,

though not limited to, include silver, cadmium, copper, nickel and zinc. It is believed that with the present invention higher efficiency in the removal of other metals such as chromium, iron and lead will also be experienced.

5 Figure 4 to which reference is made shows in table form the efficiency of heavy metal removal by commercial carbon, known as Nuchar, and by the activated carbon and ash material of the present invention on 2 test runs. All values of the metals are in mg/l.

10 Figure 5 to which reference is made lists in table form the results of analysis of the system's influent as compared with the effluent of the primary settler 10. Therefore it is seen that extremely high percentages of TSS, VSS, grease, and BOD are removed in the primary settler 10. This
15 is believed to be due to the introduction of the secondary carbon-ash slurry, i.e., the partially used carbon and ash material, into the primary settler which facilitates the settling of non-dissolved matter in the system influent.

 In the foregoing described embodiments of reactor
20 15 a constant feed rate is assumed through the various zones. In practice, the reactor may be designed with each zone as a separate unit through which the material may be fed at a different feed rate. This may be desirable to control the feed rate in the activation zone 3 to insure proper activation
25 of the material, without excessive exposure of the carbon to oxygen in the steam. Such exposure can result in too high an ash content and less carbon.

It should be appreciated that modifications may be made in the system and process hereinbefore described without departing from the spirit of the invention. For example, if the raw liquid waste is of a type in which the non-dissolved matter settles speedily without the addition of any carbon and ash material, the secondary carbon-ash slurry from settler 20 may be supplied directly to the filter, as represented by dashed line 44 rather than to contactor 12 and therefrom to the primary settler 10. Also, if the raw liquid waste is highly contaminated, so that a large amount of activated carbon and ash material is produced, some of the material may be supplied directly to contactor 10 rather than through secondary settler 20, while the rest of the material may be used for adsorbing the dissolved organic matter in the liquid in settler 20.

Furthermore, if the raw liquid waste does not contain sufficient matter to produce all the required activated carbon and ash material, commercially available activated carbon material may be added to that produced by the reactor 15 to provide the necessary amount of activated carbon and ash material. Alternately, matter may be fed directly to the reactor from an external source and added to the material supplied to the reactor from filter 17 for subsequent pyrolysis by the reactor. A source of such additional matter is represented in Figure 1 by dashed block 65.

In various industrial applications the raw liquid waste may contain some matter which is commercially useful. Such matter may first be extracted from the raw liquid waste by any of known techniques, and, thereafter, the remaining

raw liquid waste may be treated as herebefore explained. If commercially advisable, some of the extracted matter may be used as the source 65 of additional pyrolyzable matter for the reactor 15 for the production of sufficient activated carbon and ash material to sustain the system's operations. For example in the fish canning industry the raw liquid waste often contains fish waste which has a commercial value. Such fish waste may first be extracted from the liquid waste for subsequent sale. Some of it may be used as source 65 to feed the reactor 15. If the fish waste is more expensive per pound than other available pyrolyzable matter, clearly, such other matter may be used to feed the reactor 15.

A flow diagram showing one possible arrangement in which the present invention is incorporated to treat fish waste is diagrammed in Figure 6. Basically, the fish waste, produced in a fish canning operation, is directed via line 75 to a floatation and/or sedimentation stage 76. Therein, all the wet solids in the waste are separated from most of the water in which both organic and inorganic matter may be dissolved. The contaminated water is passed via line 78 to a settler 80, such as settler 20, shown in Figure 1, after being combined in a preceding contactor (not shown) such as contactor 22 (see Figure 1) with the carbon and ash slurry from reactor 15. Thus, in settler 80 the carbon and ash material removes the organic matter which is dissolved in the water. The latter can be introduced into a general water stream or sewage lines or recycled back via line 82 for use in the canning process. The carbon and ash with the adsorbed organic matter may be returned via line 84 to generate new carbon and ash material.

The wet solids from stage 76 are directed to a multi-effect evaporator 85 wherein the solids are separated from any remaining water vapor and passed to a centrifuge 86. Therein the fish solids are separated from any fish oils and any oils, such as naphthenic oil, used in the evaporator 85 as the heat transfer media. The fish solids, removed from centrifuge 86 may be exploited commercially. Some of it, if commercially desirable, may be fed to the reactor 15 to provide sufficient matter to produce the carbon and ash material. The oils separated in centrifuge 86 may be directed to an extractor 90 wherein the fish oil may be separated from the oil used in the evaporation as the heat transfer media. Such oil may be recycled back to the evaporator 86 via line 92. The water vapor from evaporator 85 may be directed to a condenser 94 and the condensed water recycled back to the canning process.

Similarly, various useful chemicals, present in the raw liquid waste of any industrial plant, may first be extracted from the raw liquid waste before subjecting it to the treatment process in accordance with the present invention.

For example, in the sugar industry in which sugar is extracted from beets, the process and pulp press waste may be treated just like the sewage, previously discussed, in order to purify the water in the process and pulp press waste for recycling in the process and to produce carbon and ash material from the solids in the waste. Some of the carbon

and ash material can be used in a settler 20 to facilitate the removal of organic matter in the flume waste which is the water used to wash the beets. Also, some of the carbon and ash material can be used to treat the Steffens house waste, to facilitate the separation of the solids therein from the liquid. The latter may be processed to extract various acids therefrom, such as by an ion exchange process, or returned back to the process for further extraction of sugar. The separated solids in the Steffens house waste can be used for the production of the carbon and ash material. A generalized block diagram of how the principles of the invention can be incorporated in treating sugar beet waste is shown in Figure 7. The various wastes, hereinbefore referred to, are discussed in a book entitled "Liquid Waste of Industry" by Nelson L. Nemerow, Library of Congress Catalog Card No. 72-106639.

As previously pointed out, the process of the present invention is very efficient in removing various metals, present in a raw liquid waste. If desired, such metals may be extracted from the activated carbon and ash material, produced by the reactor, before using the produced activated carbon and ash material in the treatment process.

Various parts of the system were described as contactors, settlers, etc. It should be appreciated that any devices performing equivalent functions may be substituted therefor. All modifications and equivalents in the parts of the system or in the steps of the process are deemed to fall within the scope of the invention as claimed in the appended claims.

This is the end of the patent specification. There are no claims attached.